MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

April 27, 2018

TO: FILE

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SUBJECT: Aquila Back Forty Mine Review Findings Relevant to Wetlands Impact Assessment

Introduction

A groundwater model was developed by Foth Infrastructure & Environment, LLC (Foth) for the purpose of estimating groundwater inflow to an open pit mine during mining operations and to provide an estimate of the drawdown associated with the open mine pit dewatering as presented in a report titled *Groundwater Modeling, Back Forty Project* prepared by Foth Infrastructure & Environment, LLC (Foth), October 2015. This groundwater model was submitted as part of 632 Nonferrous Metallic Mineral Mining Permit Application in Menominee County with the associated figures being submitted to DEQ as part of the wetlands, lakes, and streams application for the purpose of supporting the indirect wetland impact report.

Based on the DEQ review of the subject groundwater model files (that included a review of the model boundary conditions, model assumptions, grid, and model calibration), the existing Foth groundwater model as constructed is considered to be able to provide an estimate of the influx of water into the mining pit and related drawdown but with a high degree of uncertainty. Following a review of the groundwater model files, DEQ identified several issues (as noted in the following sections) that indicate that the existing Foth groundwater model is insufficient for use in assessing potential impacts to the site wetlands as a result of the proposed mining operations.

Groundwater Model Calibration Target Data Issues

According to Foth, the model as initially constructed was not achieving an acceptable mass balance error which indicates there is a problem with the conceptual model (how the site hydrogeology and flows are represented). Therefore, Foth modified the conceptual model to add River Boundary cells (river cells) to define the wetlands likely identified in the National Wetland Inventory in areas outside of the mine site as a guide for river cell placement. Only select wetlands and portions of wetlands identified onsite were defined using river cells. However all off-site and onsite wetlands were defined using the same arbitrary thickness (1 ft.), width (cell grid thickness at the wetland location), and hydraulic conductivity (K) value (1 m/day). These parameters are used to define how "fast" water will infiltrate into the aquifer and when. The select wetlands defined in the site area using the river cells helped to achieve an acceptable mass balance error in the model. However, there are no flow or stream flow measurements collected at the same time as the water levels measurements in the site wetlands so an assessment on the amount of water that is available in a particular wetland stream was not possible. Adding stream flow measurements in a groundwater model calibration is typically one means of reducing the uncertainty and "non-uniqueness" in the model calibration. Because onsite wetland and stream data is not used to define the parameters of the model, the current calibration is "non-unique" (only calibrated with limited water level data) which gives the model calibration a higher degree of uncertainty meaning there are several combinations of parameters, some of which don't match site conditions, that will give the same answer.

Foth created a steady-state model that was calibrated to the mid-point between the maximum water level and minimum water level (median) recorded at each location based on the groundwater elevation targets listed in the Foth Groundwater Report Table 4-1. However, it is not clear from the Foth groundwater modeling report which years of data were used in the calibration. A map of water levels collected in May 2012 is included in the groundwater October 2015 modeling report. Elsewhere in the application, water level data is presented from collection dates of February 2010, October 2011, December 2011, and early May 2012. At best, the steady-state model represents average annual conditions as it was calibrated based on a constant average annual recharge rate and median water level data. However, the water level target data used in the groundwater model calibration appears to be missing measurements during the wetland growing season which in this area is approximately between mid-May through the end of September. If the mine operations reduce the normal high water levels that data suggests exist in the site wetlands during the growing season (mid-May through end of September) then there could be significant impacts to these wetlands. Unfortunately, the existing groundwater model is not sufficient to evaluate the likely drawdown in the site wetlands during the period when the wetland is biologically active and the dewatering impacts to wetland function and value is not represented by the model.

Graphs of quarterly groundwater elevations recorded in the Quaternary sediments between July 2007 and September 2009 were presented in *A Hydrogeology Report: Environmental Baseline Studies* for the Aquila site by Environmental Resources Management, Inc. (ERM) dated September 2011. These graphs consistently show the gradual rise in water levels from mid-March, peaking in June, as a result of spring snowmelt and precipitation. It was noted in the ERM report that due to the rapid snowmelt and precipitation water tends to mound or pond in site areas in June. This was also observed during site visits in May and June of 2017 conducted by DEQ and King and MacGregor environmental staff. The ERM graphs show groundwater levels gradually decrease from June through November with occasional small increases observed in December.

According to information in the ERM 2011 Hydrogeology Report flow data and seasonal water level trends were documented in 2007 to 2009. For example, the report states that the wetlands along the northern and western project area boundaries drain to the Menominee River via several small, intermittent streams with flow rates ranging from 1.8 cfs and 2.3 cfs. On page 35 of the ERM Hydrogeology Report it states that "…In most cases, wetland water elevation trends are very similar to those observed in the Quaternary aquifer wells, indicating that wetlands are a surface expression of water level changes in the Quaternary aquifer…". While there is a need for updated data, this type of information is missing from the existing groundwater conceptual model which, therefore, does not reflect the site wetland hydrology

The Foth groundwater modeling report notes that the initial model appeared to have a large mass balance error and water levels were calculated to be too high based on measured data resulting in the revision in the model to reduce these calculated high water levels. However, the initial groundwater model may have been correctly capturing the higher water levels/mounding but since no June water level targets were collected, this was not incorporated correctly in the groundwater model. Foth addressed this high water level discrepancy in the model by using the river cells to define the wetlands, thereby removing the mounding. The existing model now removes water that should be mounding at the surface. Where the water levels fall below the base of the wetlands, water is now being discharged into the aquifer through the river cells. This additional inflow of water would then tend to reduce the predicted drawdown in the model. The median target water levels used in the model calibration also combine seasonal data from various years (2010, 2011, 2012) and do not represent a consistent annual median value for any month or quarter (January – December of any one year).

Groundwater Model Calibration and Target Residual Issues

A plot If the observed target values (water level measurements) versus the water level values calculated by the groundwater model is typically used to assess the quality of a groundwater model calibration. This type of calibration plot indicates how closely the measured water level data matches the water levels calculated by the groundwater model. Ideally, all the points will fall on or close to a straight line with a 45 degree slope (showing that the computed values equal the measured values). The degree of scatter about this theoretical line is a measure of the overall calibration quality. The plot of the observed water levels versus the model computed water levels from the calibrated steady-state model files shows a significant scatter around a 45 degree line indicating that the model is not that well calibrated. Attached Figure 1 is a graph of the Quaternary (model Layer 1) observed water level targets versus the model calculated water level targets from the Foth calibrated steady-state model.

In addition, a plot of the residuals from the steady-state model file indicates that there are large residuals between the measured water levels and the model calculated water levels (up to a maximum residual of 10.7 ft). These residuals also exhibit a spatial pattern of high and low values which suggests that there is likely a problem with the conceptual model or calibration. Attached Figure 2a is a map of the water level residuals with the negative (red) or positive (blue) residual level posted. The same information is presented in Figure 2b with circles added based on the relative numerical level of the residual. Figure 2b provides a better indication of the spatial bias as clusters of blue or red residuals are observed. Some of the large residuals may be the result of using a mixed year and season dataset during model calibration to represent consistent annual median calibration targets. The large residuals may also be the result of not defining the river boundary cells in the site area based on actual site data and conditions. In any case, the current use of river cells to define the wetlands onsite is not appropriate. The transient model was not correctly defined, calibrated and run to simulate conditions on a monthly basis so the flux information from the model is not available for use in the wetland water budget calculations. An appropriately designed groundwater model can be used to estimate the flux associated with each wetland and that information can supply the inflow and outflow in a wetland budget analyses.

Lack of Seasonal Variation for Inputs to Wetland Budgets

The transient groundwater model did not include simulations to evaluate seasonal changes in recharge. The recharge from November through February is often considered zero as surface soils are typically frozen. (The Foth groundwater model includes recharge for all months since the data is not scaled to represent actual site conditions.) The annual average recharge, for example, then is typically scaled to represent recharge likely to be observed in an area for the remaining months (March through September). For evaluation of wetland budgets, a groundwater model then would be used to estimate the monthly inflow or outflow from a wetland for an “average year” using the monthly transient model simulations with the scaled recharge.

The "average year" rates would then be reduced by 30% to represent a "dry year" and increased by 30% to represent a "wet year". This information is missing from the Foth groundwater model and therefore not available as input to the wetland water budget analyses.

If just the seasonal changes in water levels are considered, then under existing conditions (before mining operations) if a wetland is saturated to the soil surface (or ponded) in May, June and July (as observed at this site) there isn't any infiltration that occurs. However, if the drawdown model shows that water table will be lowered by 2 feet for example during May, June, or July, induced infiltration will occur and water levels in the wetland will be lowered under operating conditions. This has the potential to turn wetland areas into non-wetland areas depending on the infiltration rate of wetland based on soil types. As noted above, there has been no data related to infiltration rates collected in the wetlands or used in this existing groundwater model.

Therefore, if the mine operations reduce the normal high water levels that data suggests exists in the site wetlands and that sustain the wetlands during the growing season (mid-May through end of September) then there could be significant impacts to these wetlands. Unfortunately, the existing groundwater model is not sufficient to provide inputs to a wetland budget analyses or evaluate the likely drawdown and potential impact to site wetlands and streams based on the current groundwater models conceptual design.

Problems Using the MODFLOW River Boundary Cells Used to Define All Model Wetlands

In addition to the lack of seasonal calibration, the wetlands identified in the entire model domain were defined using River Boundary Cells (river cells). Foth indicates that this was done as a means of achieving a better water balance. It is noted that only select sections of a limited number of wetlands identified onsite were defined using the river cells without any justification for the random placement which is only consistent with the river cell use as a means of balancing water budget. There can be a problem with using river cells to define wetlands if the water level in the aquifer falls below the defined "river cell bottom" then flow of water into the aquifer remains constant. Since there are no adjustments for river flow and stage when using the river boundary cells, the supply of water to the aquifer from a "loosing stream" (stream discharging to the aquifer) in the wetland area can be more than the flow in the stream. Since there are no flow measurements, there is no means of assessing this effect and it is seen as a problem.

The definition of the river cells were not based on any site specific geological or hydrological data from site soil boring, piezometers, or wells. Therefore, the parameters used to define the river cells for the wetlands in the site area do not reflect the actual sediments or conditions of the wetlands. All river cells were defined using an assumed conductivity of 1 meter/day and a thickness of 1 meter. There are no onsite measurements of the vertical conductivity/infiltration rates through each wetland base. The ERM Hydrogeology Report does list limited aquifer and slug testing done in the site area in the fall of 2009 but none of the locations tested the Quaternary in any of the wetlands. Therefore, the singular river cell definition does not take into account any presence of silt, clay, or organics in the wetlands that may in reality impede the flow of water into the aquifer. In addition, the existing groundwater model no longer predicts the mounding or high water levels that are actually observed onsite in June due to spring snowmelt and precipitation. As a result, more water will likely be added to the existing groundwater model through the river cells than is actually present and that process will tend to lessen the predicted drawdown effect in the wetlands.

Based on the Foth groundwater model files, the recharge in the model over the wetlands in the site area was set to zero so that when the water levels drop below the river cell bottom, the flow into the model was intended to equal the same constant rate as the model recharge of 6 inches per year which was intended to be close to the model recharge rate of 7 inches/year (0.00048679 meters/day). However, this also has the potential of adding more water to the model than is actually available. Since there are no current stream flow or any flow measurements available in the wetland streams, the amount of water actually available cannot be assessed which adds an additional degree of uncertainty to the model predictions.

Drawdown Impacts May be Greater than Indicated in the Current Groundwater Model
As noted above, the result of the target data used in the steady-state calibration (for example, lack of consistent and complete seasonal water level targets) and the use of river cells to represent the site wetlands without the use of site specific data or conditions the drawdown impacts predicted by this groundwater model will likely be greater in most wetlands than has been presented in the Foth groundwater modeling report.

In addition, as Figure 3 (a screen shot of the drawdown contours directly from the groundwater model files) illustrates that, the existing groundwater model predicts drawdown between at least 0.5 ft to 1 ft that extends offsite to the north, west, and south of the site area. The offsite extension of drawdown is not acknowledged in the Foth groundwater report. While Foth considers this groundwater model in general to be conservative, however, the conceptual model of the wetlands are not conservative and the DEQ expects that the drawdown impacts will be greater than what has been modeled by the applicant.

Drawdown Impacts Should the Life of the Mine Extend to 16 Years Instead of 7 Years

While there are recognized problems with using the simulations from the existing Foth groundwater model to predict drawdown impacts, DEQ ran a test simulation that extended the current transient model from the 7 years mine operation time listed in the Part 632 mining permit to 16 years based on discussions that included the possibility of Aquila extending the mining operations. The 16 year extended transient model indicates that drawdown impacts could extend more significantly offsite in the Quaternary and into Wisconsin at the weathered bedrock level in the model.

Conclusion
The existing Foth groundwater model was reviewed by DEQ and determined to not be sufficient to adequately predict the potential drawdown in the site wetlands or provide useful information for wetland water budget analyses based on:

- Inappropriate target levels used for the steady-state calibration that ignores wetland growing season water levels;
- Incorrect assumptions used in the groundwater model conceptual design for wetland impact determination that ignores actual site conditions in the wetlands (for example, groundwater mounding observed in June);
- Lack of monthly seasonal variations in the transient simulations with appropriate recharge rates;
- Lack of infiltration rate information in the site wetlands;
- The use of River Boundary Cells with generic values not representative of site wetlands;
- Not all wetlands and only portions of some wetlands identified onsite are explicitly modeled using river cells. Therefore, there is no direct connection with the definitions of

the river cells to the actual wetland resource other than the information presented in the Foth groundwater modeling report that the river cells were used to help lower the mass balance error;

- The use of River Boundary Cells that are not, or cannot, be defined to correctly represent actual site wetland conditions;

Because of these identified issues, the impact to the site wetlands are expected to be greater than what has been modeled by the applicant